NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2012

RESULTS OF SHEAR FATIGUE TESTS OF JOINTS WITH $\frac{3}{16}$ -INCH-

DIAMETER 24S-T31 RIVETS IN 0.064-INCH-

THICK ALCLAD SHEET

By Marshall Holt

Aluminum Company of America



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Pages 44 and 45: Figures 28 and 29 are in error and should be replaced with corrected figures attached hereto.

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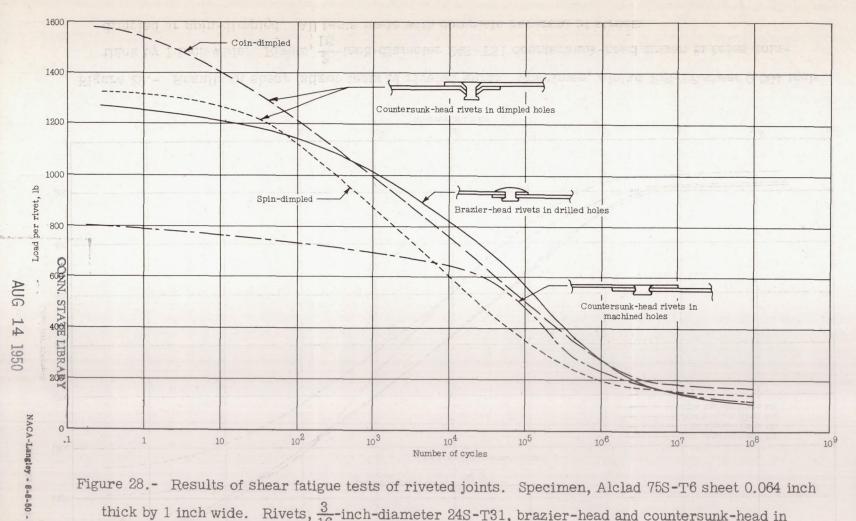


Figure 28.- Results of shear fatigue tests of riveted joints. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. Rivets, $\frac{3}{16}$ -inch-diameter 24S-T31, brazier-head and countersunk-head in different types of holes. All tests made with complete reversal of stress.

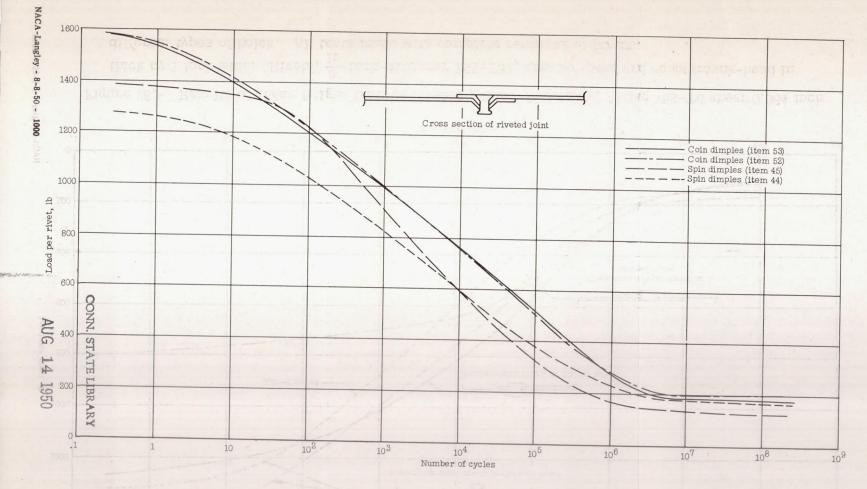


Figure 29.- Results of shear fatigue tests of riveted joints. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. Rivets, $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk-head driven in holes coindimpled or spin-dimpled. All tests made with complete reversal of stress.

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TECHNICAL NOTE 2012

RESULTS OF SHEAR FATIGUE TESTS OF JOINTS WITH $\frac{3}{16}$ -INCHDIAMETER 24S-T31 RIVETS IN 0.064-INCHTHICK ALCLAD SHEET

By Marshall Holt

SUMMARY

Shear fatigue tests were made of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 (-T)¹ rivets in 0.064-inch-thick Alclad sheet of the following high-strength aluminum alloys: Alclad 24S-T3 (-T),¹ Alclad 24S-T81, Alclad 24S-T36 (-RT),¹ Alclad 24S-T86, Alclad 75S-T6 (-T),¹ Alclad 14S-T4 (-W),¹ and Alclad 14S-T6 (-T).¹ One series of tests was made on joints with $\frac{3}{16}$ -inch-diameter 17S-T31 (-T)¹ rivets in 0.064-inch-thick Alclad 75S-T6 (-T)¹ aluminum alloy.

The results showed that the design of the joint gives a wider range of fatigue strengths than does the choice of material from the group studied. The results also showed that no one sheet alloy showed superiority over the others.

INTRODUCTION

The research program of the Aluminum Research Laboratories has included the fatigue testing of joints of various types using aircraft—size rivets. The results of some of the tests have been presented in references 1 and 2.

It is the purpose of this report to expand the field covered by reference 2 and to summarize the available test data of joints with $\frac{3}{16}$ -inch-diameter 24S-T3l rivets in 0.064-inch-thick Alclad sheet of the high-strength aluminum alloys.

Former temper designation given in parentheses.

MATERIALS AND SPECIMENS

Alclad sheet of the following alloys and tempers was used in these tests: Alclad 24S-T3, Alclad 24S-T81, Alclad 24S-T36, Alclad 24S-T86, Alclad 75S-T6, Alclad 14S-T4, and Alclad 14S-T6. The actual thicknesses of the sheet and of the Alclad coating (each side) are given in table I. The tensile properties are given in table I and all the values satisfy the respective specification requirements. They are also in good agreement with the typical values. The artificially aged materials were obtained from the same lots as the corresponding naturally aged materials.

All the rivets used were 3/16 inch in diameter; 24S-T31 was used for all the rivets except for one set which was of 17S-T31. They were heat-treated, quenched, refrigerated, and driven cold immediately after removal from the refrigerant (-T31 temper). As noted in tables II and III, the manufactured heads of some were of the brazier type and some were countersunk at 100°. The driven heads were all flat. For items 36, 38, 39, and 43, the sheet was machine-countersunk while for items 44, 45, 52, and 53 the sheet was dimpled either by spin-dimpling or coin-dimpling as noted. The rivets were allowed to age at room temperature for at least 4 days before testing.

The individual fatigue specimens were simple lap joints containing a single rivet. They were I inch wide and the lap was 3/4 inch long as shown in figure 1. They were cut from panels 20 inches long containing 16 rivets as shown in figure 2. After sawing, the edges of the specimens were finished by machining in the longitudinal direction. The specimens for static test also contained a single rivet and were cut from panels as shown in figure 3.

METHODS OF TESTING

Three different machines were used during the testing of the fatigue specimens and, judging from the overlapping of the plotted data, the fatigue strengths were not influenced by the machine used. The machines are shown in figures 4, 5, and 6. The ARL rotating—beam fatigue machine shown in figure 4 was designed and built at the Aluminum Research Laboratories in 1942 and operates at 1750 rpm. It was used for most of the tests. The adapters for testing a set of four specimens are shown in figure 7. During the test the adapter and specimens formed part of a rotating beam, the central portion of which was subjected to a uniform bending moment. The rivets were thus subjected to a cyclic shearing load which varied from a maximum in one direction to the same value in the opposite direction. The 2—inch

rotating-beam fatigue machine is shown in figure 5. It was designed and built at Aluminum Research Laboratories in 1930 and is described in reference 3. This machine was originally intended for testing rotating solid-beam specimens having a diameter of 2 inches at the test section. By means of the adapters shown in figure 8 it is made suitable for testing these small riveted joints under completely reversed loading. It operates at 1400 rpm. A Krouse direct-stress fatigue machine having a maximum capacity of 5000 pounds is shown in figure 6. This machine is also provided with adapters for testing a set of four specimens. It operates at 1500 rpm. Although this machine is adjustable to give any desired loading cycle, the tests were made with completely reversed stresses. Each of these machines is equipped with a limit switch which automatically stops the machine when a specimen fails. Each also has a counter for determining the number of cycles of stress. In the tests in which the expected life of the specimen was less than about 1000 cycles, the specimen was rotated by hand and the number of cycles counted.

Usually only one of the four joints fails in fatigue and the specimen then collapses. Occasionally it is difficult to determine the location of the initial failure, whether in the rivet or sheet, because the joints are mutilated considerably by the time the machine comes to rest.

RESULTS AND DISCUSSION

The individual test results are given in table II with information on the sheet alloy, type of rivet, preparation of the hole, and location of initial failure. The data are shown as S-N curves in figures 9 to 24. Table III summarizes the indicated fatigue strengths for certain numbers of cycles of stress. The data suggest the following comparisons.

Various Alloys and Tempers

As shown in figures 25 and 26 all the S-N curves for the various alloys and tempers of Alclad sheet used in this investigation are of the same general shape and for each type of joint the curves lie fairly close together so that all of them can be covered by a relatively narrow scatter band. This is particularly true of the joints with brazier—head rivets where the variables of making the specimens can be kept in closer control. No one sheet alloy shows a consistent superiority over all of the others in these tests but it is interesting to note that Alclad 24S-T3 is generally on the high side of the group.

Design of Joint

The data in figures 27 and 28 show that the design of the joint, whether using rivets with protruding heads or with flush heads, gives a wider range of fatigue strengths than does the choice of the material from the group studied in this investigation. For high loads per rivet and small numbers of cycles, the protruding—head rivets in drilled holes are superior to flush—head rivets in machine—countersunk holes. The relative strength of joints with dimpled holes depends on the method used in dimpling the sheet. In the case of Alclad 75S—T6 sheet, the data in figure 29 indicate that coin—dimpling is superior to spin—dimpling. For lives greater than 106 cycles, the fatigue strengths of all joints lie within a rather narrow scatter band.

Aluminum Research Laboratories
Aluminum Company of America
New Kensington, Pa., June 1, 1949

REFERENCES

- 1. Andrews, H. J., and Holt, M.: Fatigue Tests on 1/8-Inch Aluminum Alloy Rivets. NACA TN 971, 1945.
- 2. Moore, R. L., and Hill, H. N.: Comparative Fatigue Tests of Riveted Joints of Alclad 24S-T, Alclad 24S-T81, Alclad 24S-RT, Alclad 24S-T86, and Alclad 75S-T Sheet. NACA RB 5F11, 1945.
- 3. Templin, R. L.: The Fatigue Properties of Light Metals and Alloys. Proc. A.S.T.M., vol. 33, part II, 1933.

ACA TN 2012

TABLE I.— MECHANICAL PROPERTIES OF SHEET USED IN FATIGUE TESTS OF JOINTS WITH $\frac{3}{16}$ — INCH—DIAMETER 24s—T31 RIVETS IN 0.064—INCH—THICK ALCLAD SHEET

		Thi	ckness		Parall	lel to di:	rection of	rolling	Norma	al to dire	ection of re	olling
Item	Alloy and temper	(in.)	Material	Tensile	Tensile	Elongation	Com- pressive	Tensile	Tensile	Elongation	Com- pressive
1 cem	ATTOY and temper	Sheet	Alclad (coating)	Ma del la l	strength (psi)	yield strength (psi)	in 2 in. (percent)	yield strength (psi)	strength (psi)	yield strength (psi)	in 2 in. (percent)	yield strength (psi)
23	aAlclad 24S-T36	0.066	0.0016	62968–1	71,900	60,900	15.5		70,050	54,100	14.0	
24	aAlclad 24S-T86	.068	.0016	62968-2	73,550	69,650	6.5	×	72,650	68,200	6.3	
25, 43	aAlclad 75S-T6	.064	.0018	63317	80,350	71,200	14.0		78,800	66,850	14.0	
26	Alclad XA75S-T6	.064	.0018	66420	70,450	60,850	11.0		70,450	58,900	11.0	
27, 39	aAlclad 24S-T3	.064	.0016	67793-1	68,800	51,700	20.3		66,850	44,400	19.0	
28	aAlclad 24S-T81	.064	.0016	67793-2	68,900	62,500	6.5	61,750	67,250	60,150	6.3	62,400
35, 36	Alclad 145-T4	.064	.0018	74466	65,500	47,300	21.5	37,050	64,850	40,350	20.5	43,600
37, 38	Alclad 145-T6	.064	.0018	74467	68,850	62,050	11.0	61,650	68,200	60,700	9.5	64,300
1414	Alclad 75S-T6	.063	.0021	75935					79,600	68,350	12.5	
45	Alclad 75S-T6	.065	.0022	75977					78,050	67,000	11.3	
52, 53	Alclad 75S-T6	.063	.0022	80503					78,350	66,500	11.8	

[.] aSee also reference 2.

TABLE II. DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS; JOINTS WITH $\frac{3}{16}$ -INCH-DIAMETER 24S-T31 RIVETS IN 0.064-INCH-THICK ALCLAD SHEET

All tests made with complete reversal of stress

Item	Sheet alloy (1)	Manufactured head style of rivet	Specimen	Load per rivet (lb)	Number of cycles	Type of failure	Machine used (2)	Reference
26	Alclad XA75S-T6	Brazier	66420-3 -2 -1 -4 -3	1230 350 250 200 150	Static 401,500 1,327,200 1,437,500 12,699,600	Rivet Sheet Sheet Sheet Sheet	A ARL ARL ARL ARL	Figure 12
28	Alclad 24s-T81	Brazier	67793-2-1 -2 -3 -2-4	1000 800 650 1150	800 9,700 39,900 93	Rivet Rivet Sheet Rivet	K K K	Figure 14
35	Alclad 14S-T4	Brazier	74466A-2 -4-7 -4-8 -4-6 -3-5 -3-11 -2-4 -3-12 -2-3 -4-13 -3-10 -2-2 -2-1 -4-9 -4-15	1260 1100 1000 900 550 501 500 413 400 393 307 300 200 200 174 161	Static 11 2,628 8,829 99,400 82,800 125,400 195,400 303,600 185,500 820,800 1,265,200 7,021,600 8,351,100 3,739,000 114,870,100	Rivet Buckled Buckled Sheet Rivet Sheet Uncertain Sheet Uncertain Sheet Sheet Sheet Sheet Sheet Sheet None	A 2-in. 2-in. 2-in. K ARL K ARL K ARL K ARL K K K K K K K K K K K	Figure 15

¹Additional data given in reference 2. ²A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating—beam fatigue machine; K, Krouse direct—stress fatigue machine; 2-in., rotating-beam fatigue machine for 2-in.-diameter specimens.

Item	Sheet alloy	Manufactured head style of rivet	Specimen	Load per rivet (1b)	Number of cycles	Type of failure	Machine used (2)	Reference
36	Alclad 14S—T4	Countersunk (machine)	74466B -2-8 -2-7 -4-16 -4-15 -2-6 -1-4 -2-5 -4-13 -1-1 -1-2 -4-10 -4-14	870 800 750 700 500 451 450 400 350 313 300 201 200 174 147	Static 671 1,550 10,394 68,500 75,700 4,600 68,800 500,700 470,400 832,900 3,758,400 6,089,800 2,965,800 5,247,200 454,530,800	Rivet Rivet Rivet Sheet Uncertain Sheet Rivet Rivet Sheet Sheet Sheet Sheet Sheet Sheet Sheet Sheet Sheet	A 2-in. 2-in. 2-in. 4RL K ARL ARL ARL ARL K ARL K ARL K K K K K K	Figure 16
37	Alclad 145-T6	Brazier	74467-A-4-8 -4-9 -3-7 -3-6 -2-4 -2-3 -3-10 -2-2 -2-1 -4-11 -3-5	1250 1150 1050 950 550 400 350 300 200 175 150	Static 108 1,326 6,507 83,800 372,400 498,500 1,366,100 4,329,800 4,915,600 100,243,200	Rivet Uncertain Rivet Sheet Sheet Uncertain Uncertain Uncertain Sheet Sheet None	A ARL ARL ARL ARL ARL ARL ARL ARL ARL AR	Figure 17
38	Alclad 145-T6	Countersunk (machine)	74467B -2-9 -2-7 -2-8 -4 -2-6 -3-11 -4-2 -3-12 -4-3 -2-5 -3-10 -4-13 -4-14	900 800 750 700 695 500 500 450 400 375 300 205 150 126	Stat1c 13 50 7,579 4,500 45,600 87,500 78,900 139,100 221,300 447,100 2,581,600 5,840,300 5,432,000 15,730,600 213,773,800	Rivet Rivet Rivet Sheet Sheet Uncertain Rivet Rivet Sheet Sheet Sheet Sheet Sheet Sheet Sheet None	A 2-in. 2-in. k ARL	Figure 18

TABLE II. - DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS - Continued

¹ Additional data given in reference 2.

²A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating-beam fatigue machine; K, Krouse direct-stress fatigue machine; 2-in., rotating-beam fatigue machine for 2-in.-diameter specimens.

TABLE II. - DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS - Continued

Item	Sheet alloy (1)	Manufactured head style of rivet	Specimen	Load per rivet (lb)	Number of cycles	Type of failure	Machine used (2)	Reference
39	Alclad 24S—T3	Countersunk (machine)	67793-1-9 -1-8 -3-7 -2-5 -1-3 -1-2 -1-1 -2-4 -3-10 -3-11	1010 900 750 550 450 350 250 200 180 150	Static 483 12,422 96,300 183,600 383,000 2,197,200 5,507,200 14,122,300 342,719,000	Rivet Rivet Sheet Sheet Rivet Sheet Sheet Sheet Sheet None	A 2-in. 2-in. ARL	Figure 19
43	Alclad 75S-T6	Countersunk (machine)	63317 -3-9 -3-8 -2-5 -1-3 -1-2 -1-1 -2-4 -2-6 -3-7	800 750 700 550 450 350 250 200 150	Static 28 657 60,700 134,800 260,300 876,600 2,135,800 5,741,600 100,552,000	Rivet Rivet Sheet Sheet Sheet Sheet Sheet None	A A 2—in. ARL	Figure 20
44	Alclad 758-T6	Countersunk (spin dimple)	75935 -2-3 -2-1 -2-2 -3-5 -3-6 -4-7 -8 -9	1270 400 300 200 170 160 996 808 604	Static 44,800 291,800 3,033,500 3,524,700 288,290,800 127 1,725 14,500	Rivet Sheet Sheet None Sheet Sheet	A ARL ARL ARL ARL ARL K K K	Figure 21

lAdditional data given in reference 2.

²A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating—beam fatigue machine; K, Krouse direct—stress fatigue machine; 2—in., rotating—beam fatigue machine for 2—in.—diameter specimens.

TABLE II. - DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS - Concluded

Item	Sheet alloy (1)	Manufactured head style of rivet	Specimen	Load per rivet (lb)	Number of cycles	Type of failure	Machine used (2)	Reference
45	Alclad 758—T6	Countersunk (spin dimple) (175-T31 rivets)	75977 -1-7 -1-1 -1-3 -1-4 -2-8 -1-6 -2-9 -2-13 -1-10 -3-11 -3-12 -3-14	1390 350 300 200 150 135 120 1284 994 818 600 600 424	Static 229,600 159,100 528,300 841,400 46,986,300 207,763,700 60 532 2,600 3,400 6,800 36,000	Sheet Sheet Sheet Sheet Sheet None Sheet Sheet Sheet Sheet Sheet Sheet Sheet	ARL ARL ARL ARL ARL ARL K K K K	Figure 22
52	Alclad 758—T6	Countersunk (coin dimple)	80503C -3-11 -1-3 -1-2 -2-5 -1-4 -2-6 -2-7 -2-8 -1-1 -3-12	1580 930 450 350 300 250 230 220 200 200	Static 2,200 188,500 368,700 1,248,400 3,264,400 2,775,300 1,479,900 12,296,600 442,735,100 43	Sheet Sheet Uncertain Sheet Sheet Sheet Sheet Sheet Sheet Sheet Sheet None. Sheet	K ARL ARL ARL ARL ARL ARL ARL ARL	Figure 23
53	Alclad 758—T6	Countersunk (coin dimple)	80503H -3-12 -3-10 -3-9 -3-11 -2-8 -1-3 -1-2 -2-7 -1-4 -2-5 -2-6	1200 1000 823 750 555 500 400 300 220 190	Static 137 1,100 4,500 10,500 111,300 119,700 295,300 683,800 2,344,400 3,480,900 114,591,600	Sheet Sheet Sheet Uncertain Sheet Sheet Sheet Sheet Sheet Sheet None	K K K ARL ARL ARL ARL ARL ARL	Figure 24

lAdditional data given in reference 2.

²A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating—beam fatigue machine; K, Krouse direct—stress fatigue machine; 2—in., rotating—beam fatigue machine for 2—in.—diameter specimens.

TABLE III.— FATIGUE STRENGTES AT VARIOUS NUMBERS OF CYCLES; JOINTS WITH $\frac{3}{16}$ —INCH—DIAMETER

24S-T31 RIVETS IN 0.064-INCH-THICK ALCLAD SHEET

All tests made with complete reversal of stress; stress ratio, -1

Item	Alclad sheet alloy	Manufactured head style of rivet	Static strength (b)	Fatigue strength at various numbers of cycles (lb per rivet) (b)								
02		(a)		10	102	103	104	105	106	107	108	
23	°245-T36	Brazier	1250R	1190E	1125E	1010E	825E	590S	330S	170s	1208	
24	°245-T86	Brazier	1250R	1185E	1120E	1030E	850E	550R	260s	1258	1058	
25	°75S-T6	Brazier	1270R	1210R	1140R	1015R	825R	580R	2858	155S	1158	
26	XA75S-T	Brazier	1230R	1120E	975E	800E	630E	430E	255S	155S	150E	
27	°24S-T3	Brazier	1255R	12008	11408	10358	8558	590S	3158	2108	185S	
28	°245-T81	Brazier	1250R	1180R	1110R	990R	800R	555℧	290S	125S	1008	
35	14S-T4	Brazier	1260R	1200R	1145R	1050R	880R	495R	2850	195S	1608	
36	14S-T4	Countersunkd	870R	865R	845R	780R	6100	4300	265S	160s	1308	
37	145-176	Brazier	1250F	12050	11550	1065R	895R	535S	300S	1708	155S	
38	145-16	Countersunkd	900R	815R	760R	710R	640R	435S	240s	1258	1058	
39	24S-T3	Countersunkd	1010R	970R	935R	875R	770R	550R	2750	1908	1658	
43	75S-I6	Countersunkd	800R	765R	730R	695R	6400	4900	2400	155U	1250	
44	75S-T6	Countersunk	1270R	1040E	830E	640E	485E	360s	240S	1805	1658	
45	75S-T6	Countersunke	1390R	1080E	940E	790E	610E	3800	1558	1408	1308	
52	75S-I6	Countersunkf	15800	13900	12000	980s	745S	500S	2858	2008	2005	
53	75S-T6	Countersunkg		1400R	1210R	990R	765U	520S	2808	1858	1808	

aDriven heads were all flat.

bLetters following fatigue strengths have the following meanings: R, rivet failure; S, sheet failure; U, uncertain type of failure; E, estimated from incomplete S-N curve; F, sheet buckled, rivets sheared at 1365 pounds.

CReported in reference 2. dMachine—countersunk.

espin-dimpled holes.

fCoin-dimpled at room temperature.

gCoin-dimpled with heated tools.

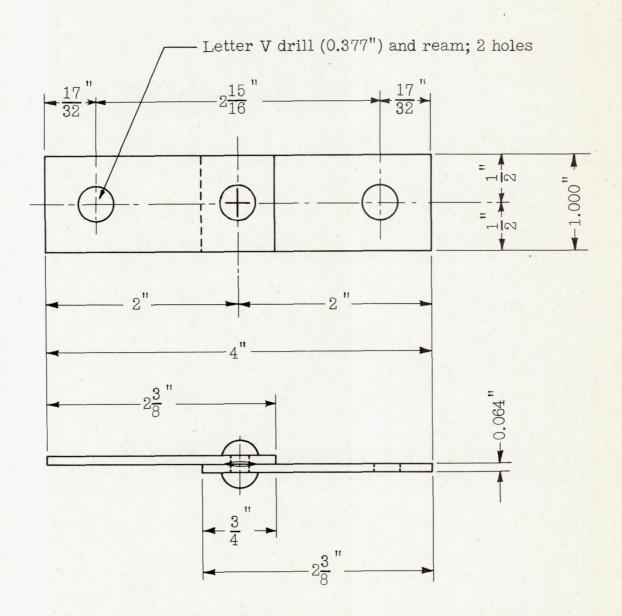


Figure 1.- Riveted specimen, 0.064-inch-thick (14-gage) sheet. Maximum rivet size, $\frac{3}{16}$ -inch diameter.

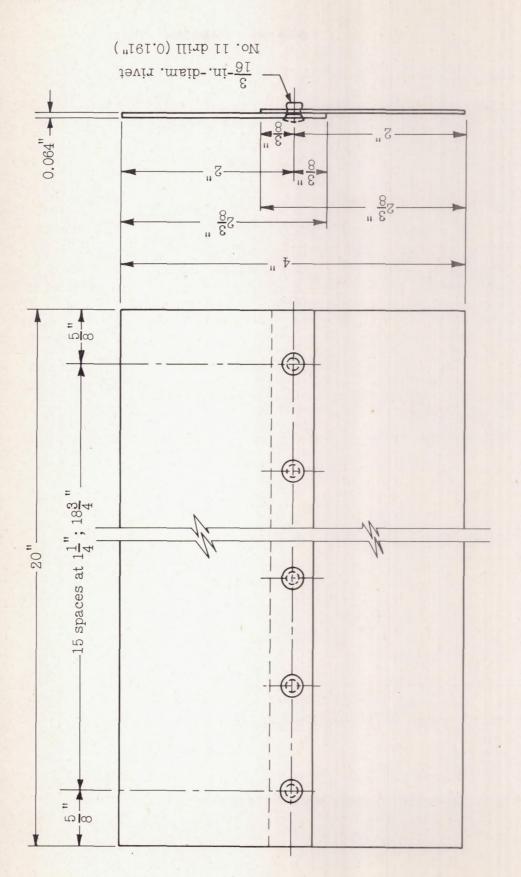


Figure 2.- Panel for fatigue tests of riveted joints.

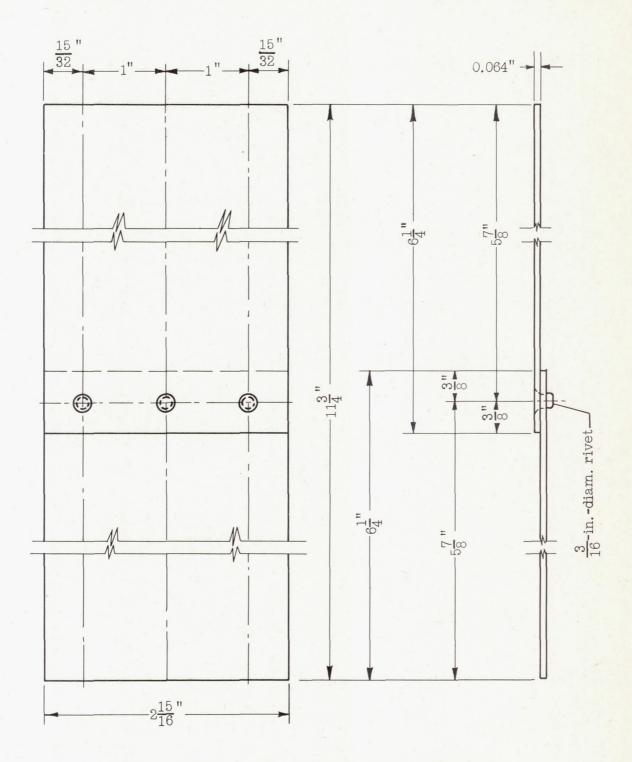


Figure 3.- Panel for static tests of riveted joints.

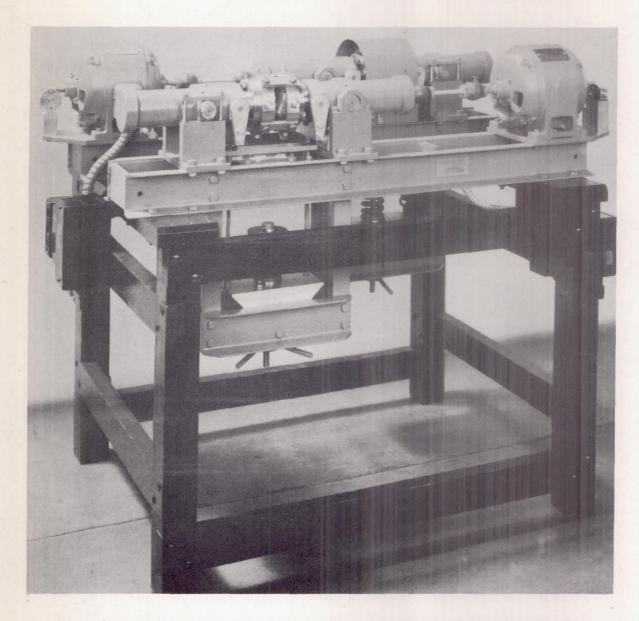
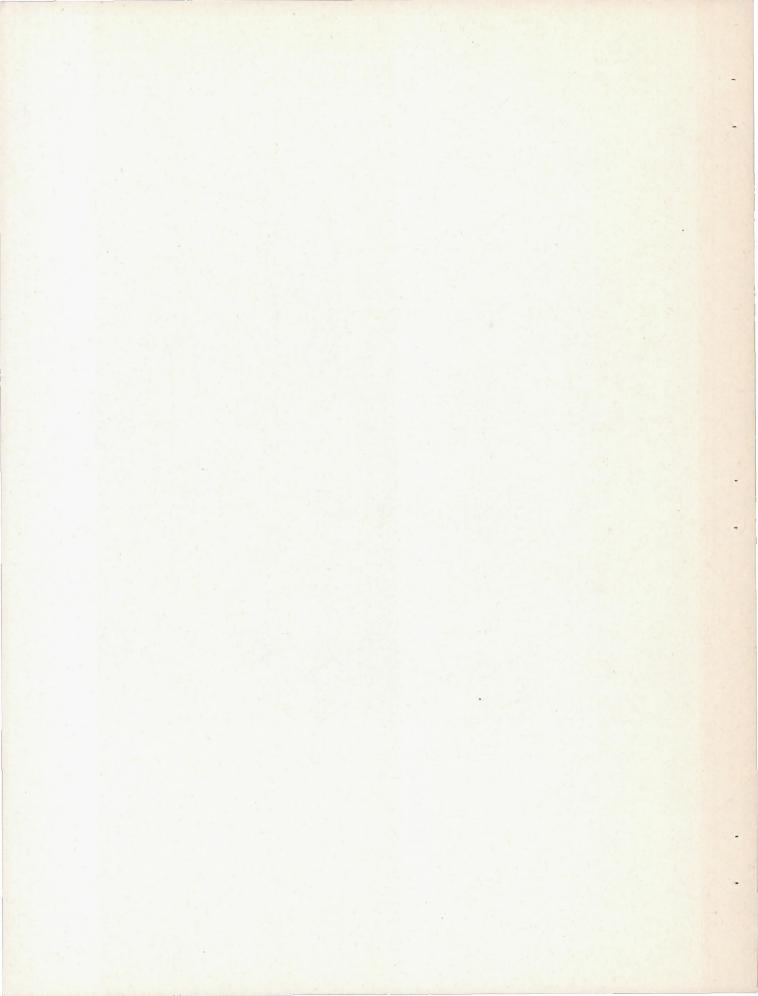


Figure 4.- ARL rotating-beam fatigue testing machine designed and built at Aluminum Research Laboratories in 1942.



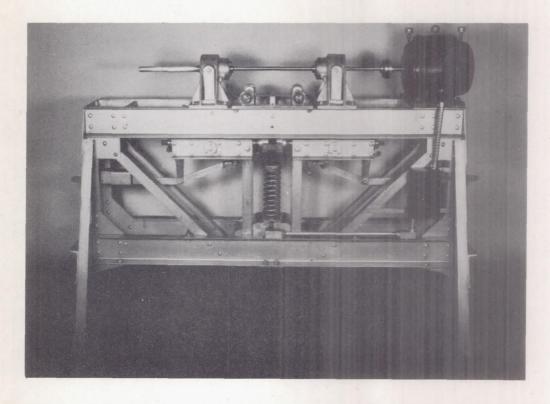
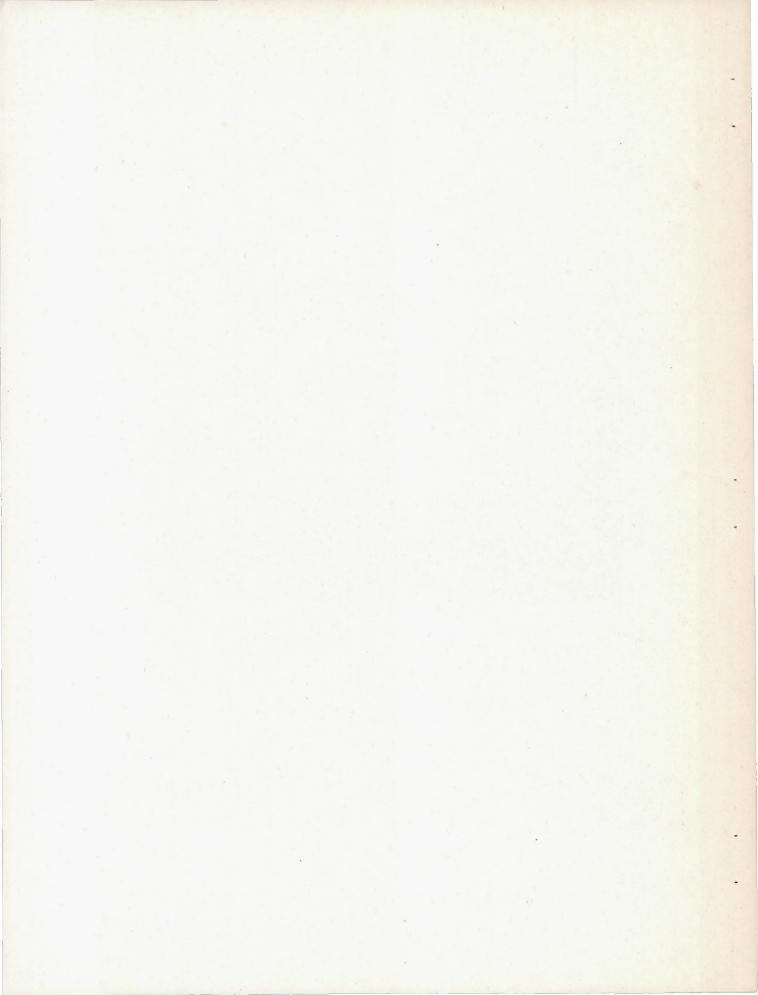


Figure 5.- The 2-inch rotating-beam fatigue testing machine designed and built at Aluminum Research Laboratories in 1930.



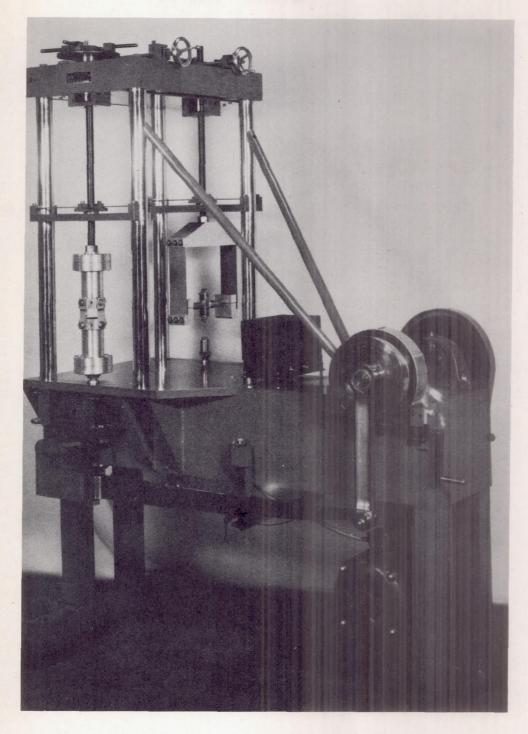
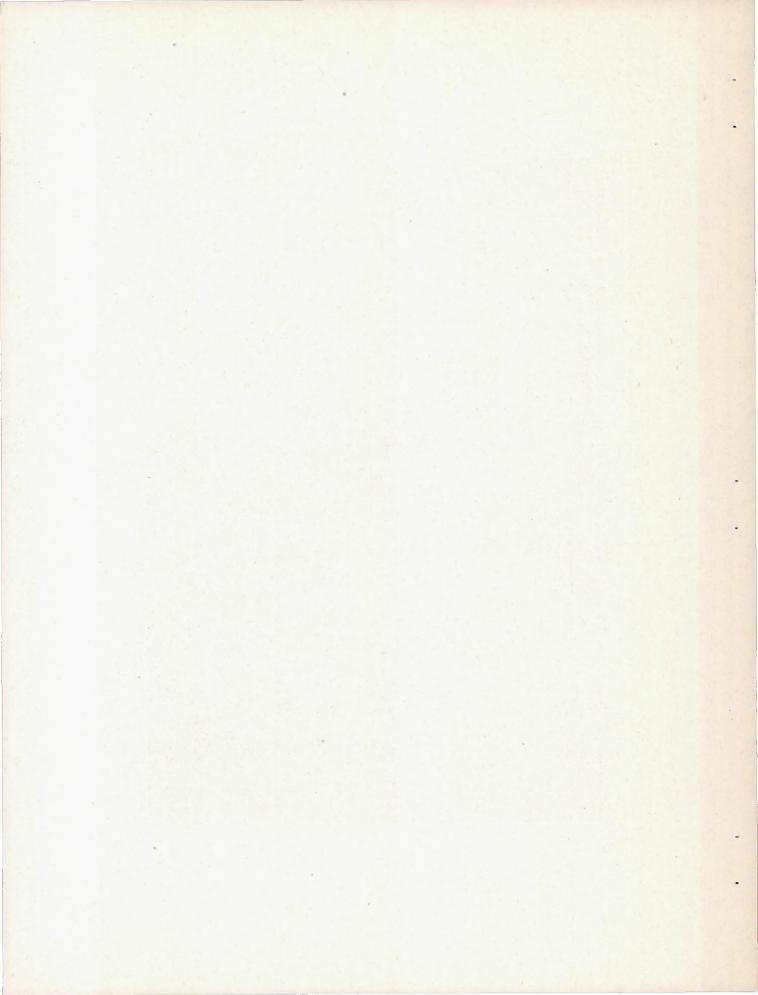


Figure 6.- Krouse direct-stress fatigue testing machine.



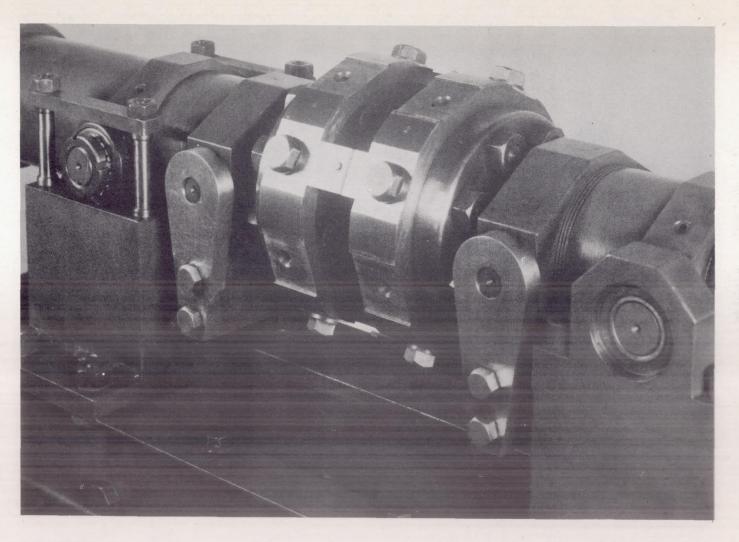
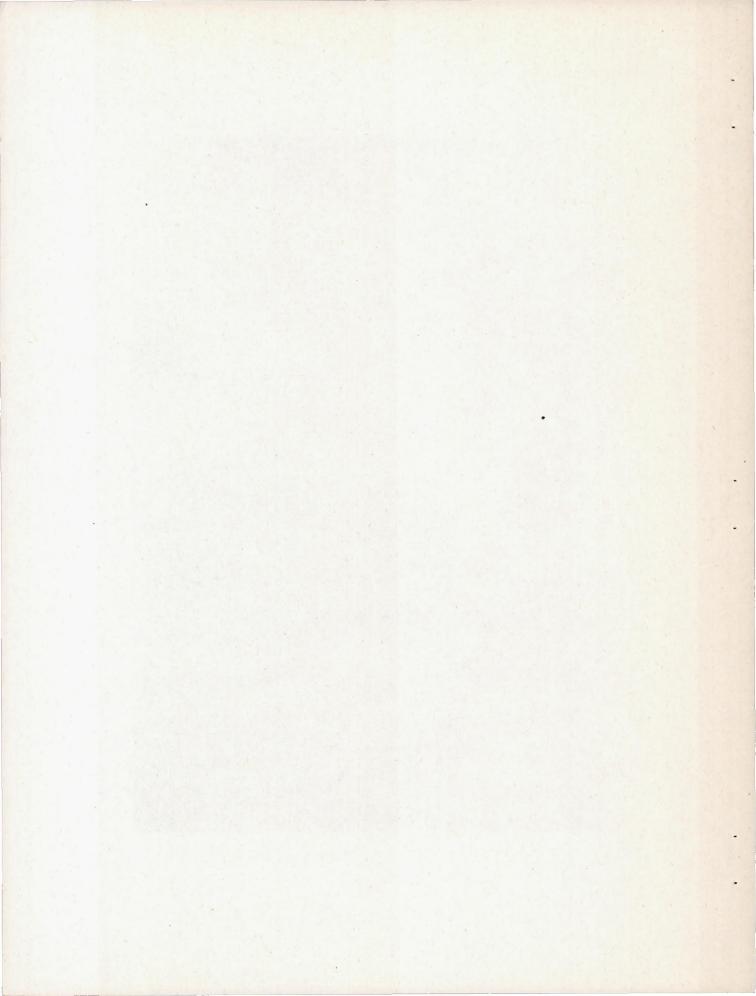


Figure 7.- Fixtures for loading riveted joints in ARL rotating-beam fatigue machine.



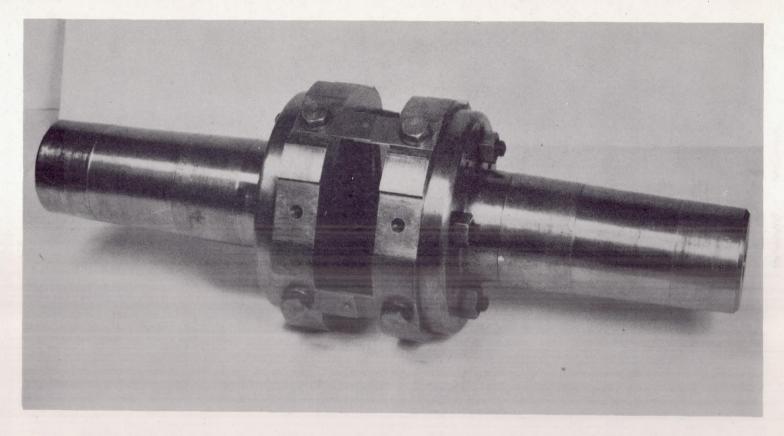
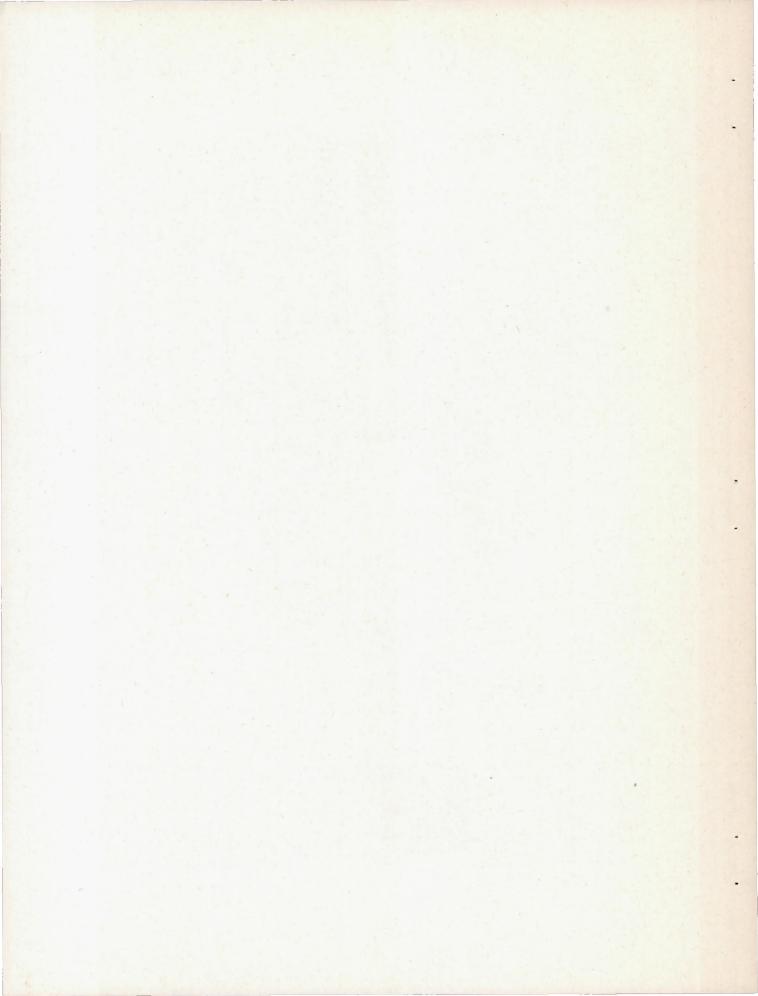


Figure 8.- Fixtures for loading riveted joints in 2-inch rotating-beam fatigue machine.



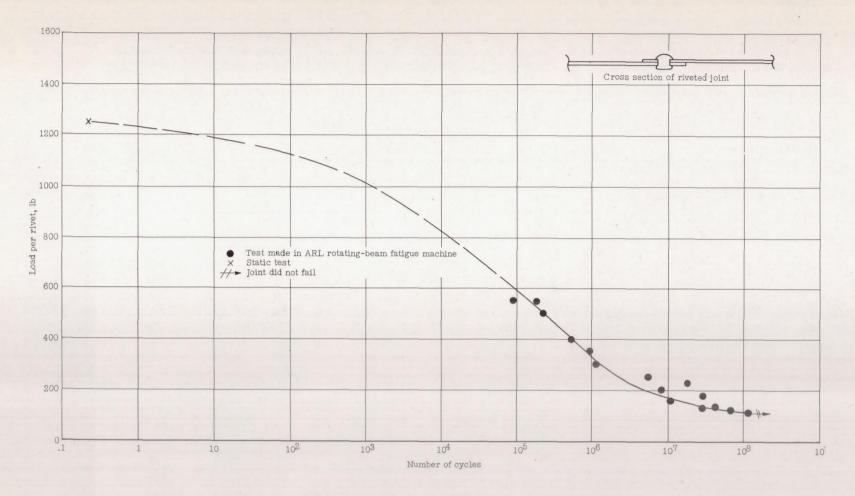


Figure 9.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T36 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II, reference 2. All tests made with complete reversal of stress.

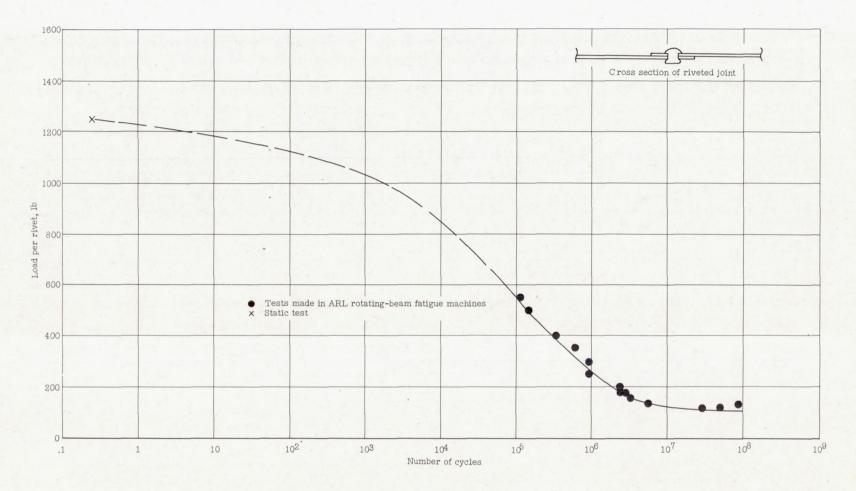


Figure 10.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T86 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II, reference 2. All tests made with complete reversal of stress.

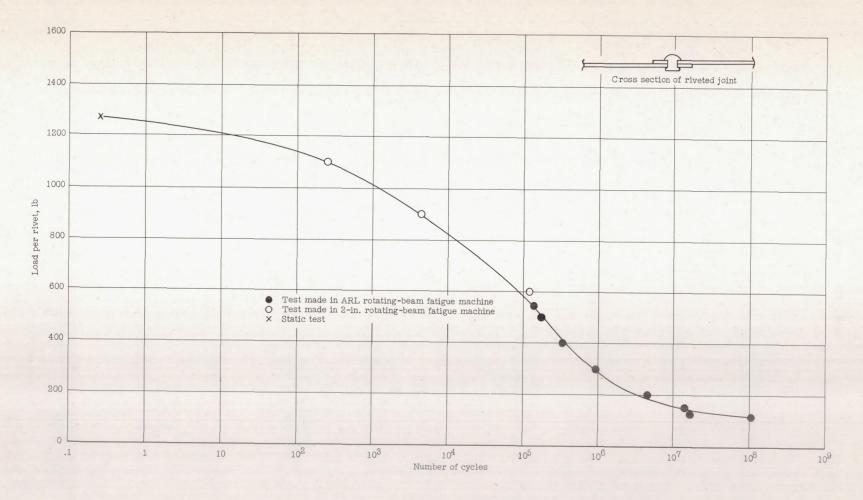


Figure 11.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II, reference 2. All tests made with complete reversal of stress.



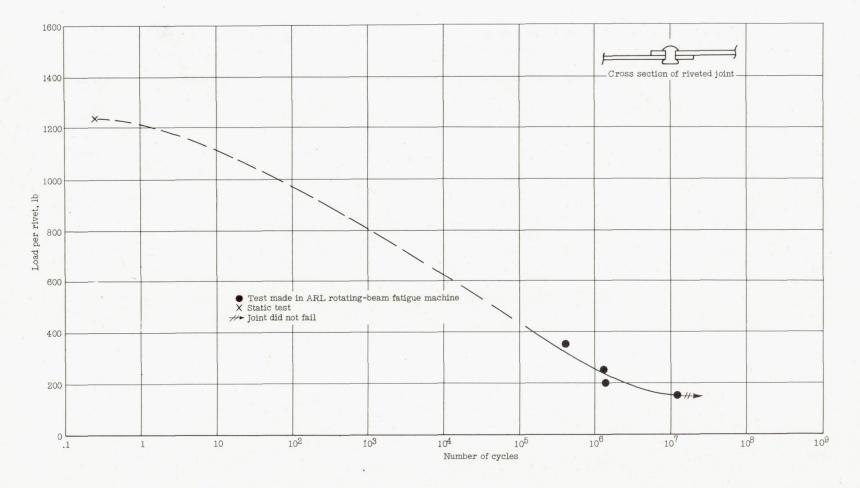


Figure 12.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad XA75S-T sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 26, table II of present paper. All tests made with complete reversal of stress.

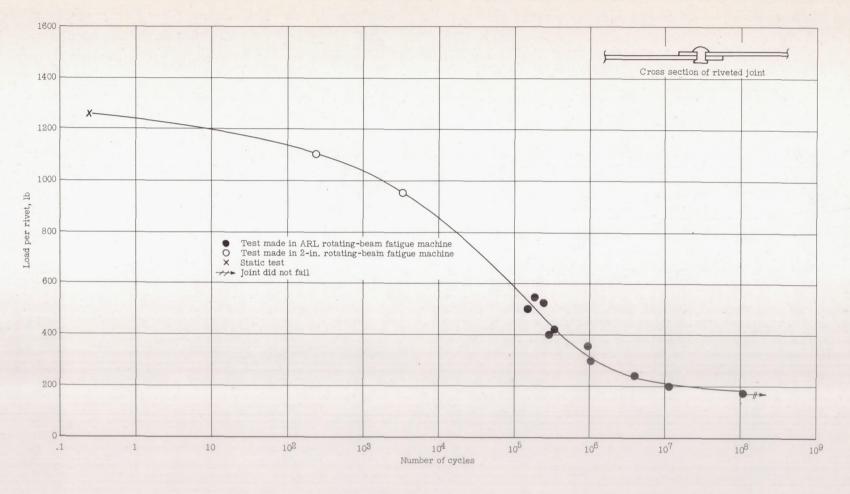


Figure 13.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T3 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II of reference 2. All tests made with complete reversal of stress.

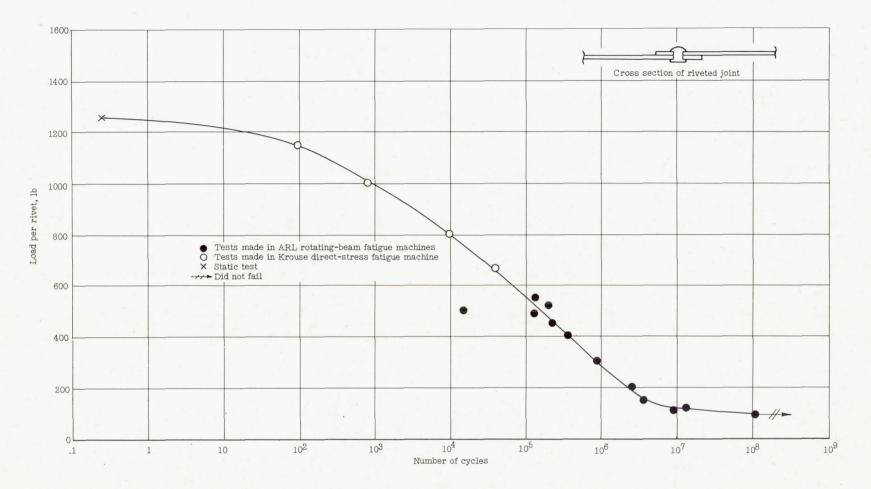


Figure 14.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T81 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II of reference 2 and item 28, table II of present paper. All tests made with complete reversal of stress.

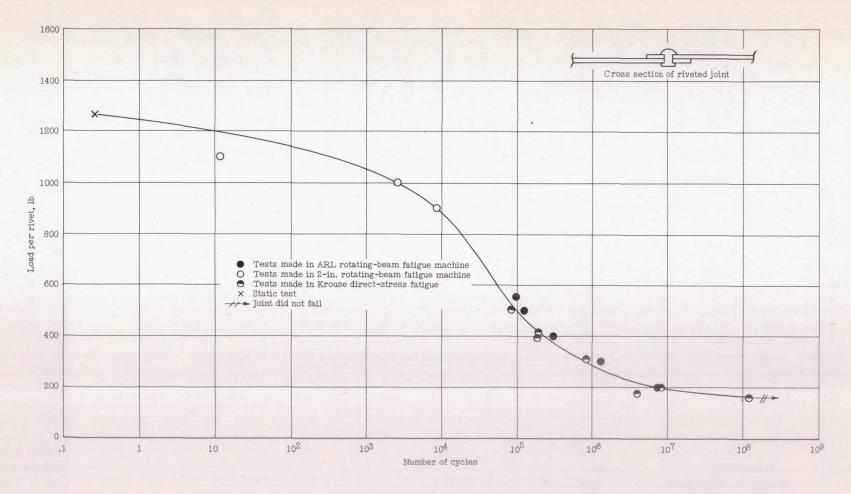


Figure 15.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 14S-T4 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 35, table II of present paper. All tests made with complete reversal of stress.



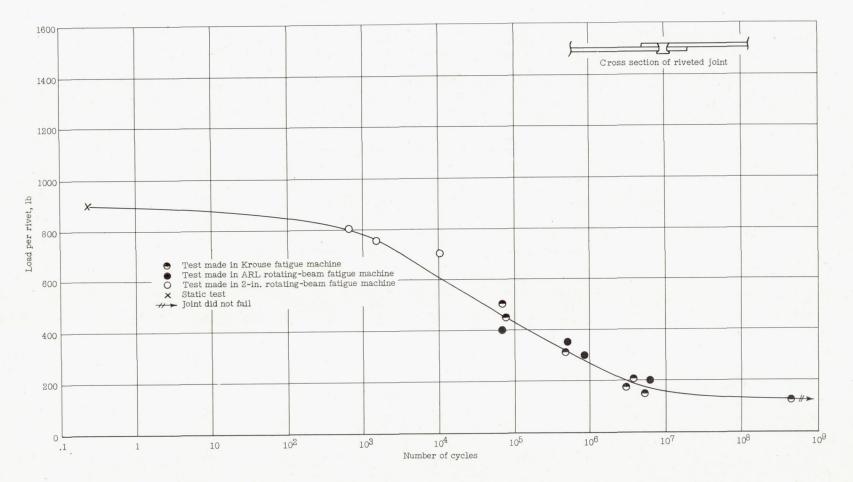


Figure 16.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 14S-T4 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 36, table II of present paper. All tests made with complete reversal of stress.

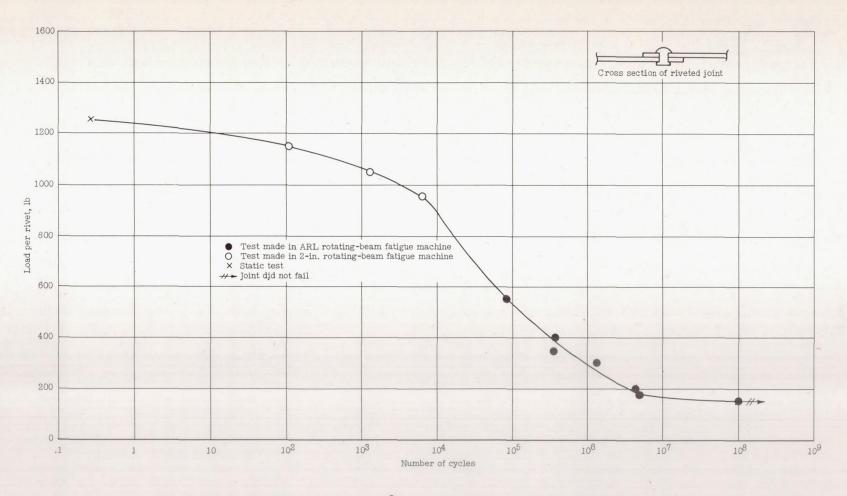


Figure 17.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 14S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 37, table II of present paper. All tests made with complete reversal of stress.

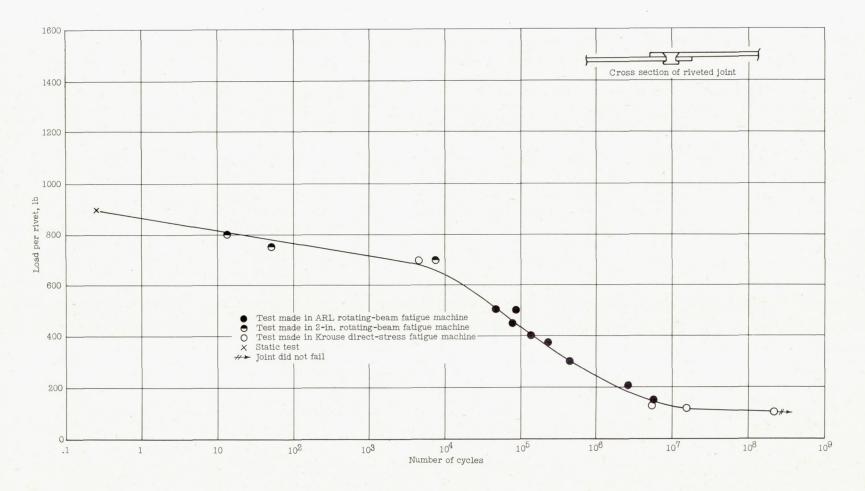


Figure 18.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 14S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 38, table II of present paper. All tests made with complete reversal of stress.

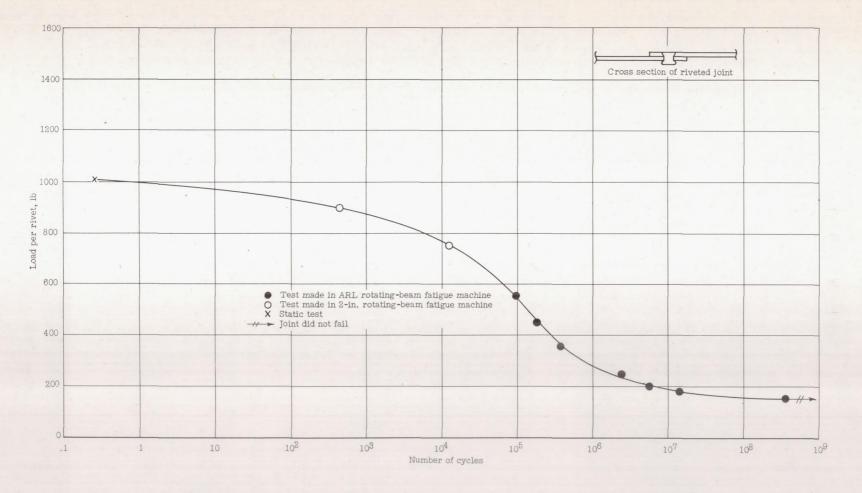


Figure 19.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 24S-T3 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 39, table II of present paper. All tests made with complete reversal of stress.

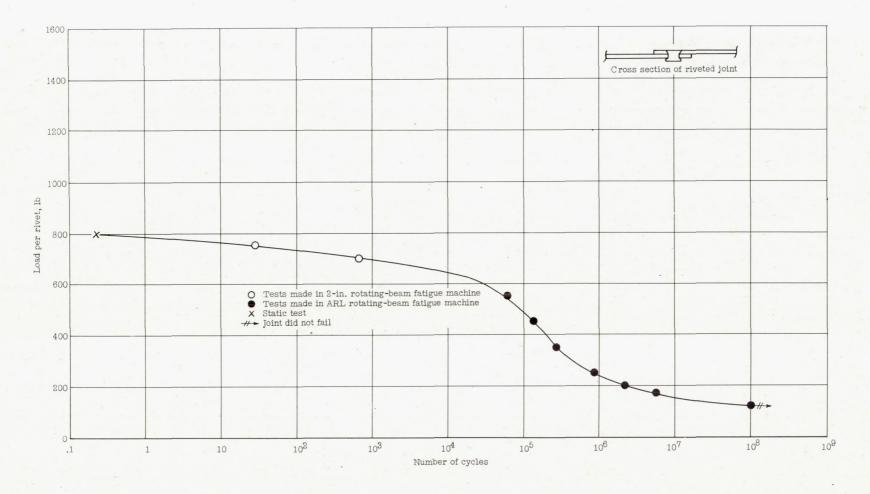


Figure 20.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 43, table II of present paper. All tests made with complete reversal of stress.

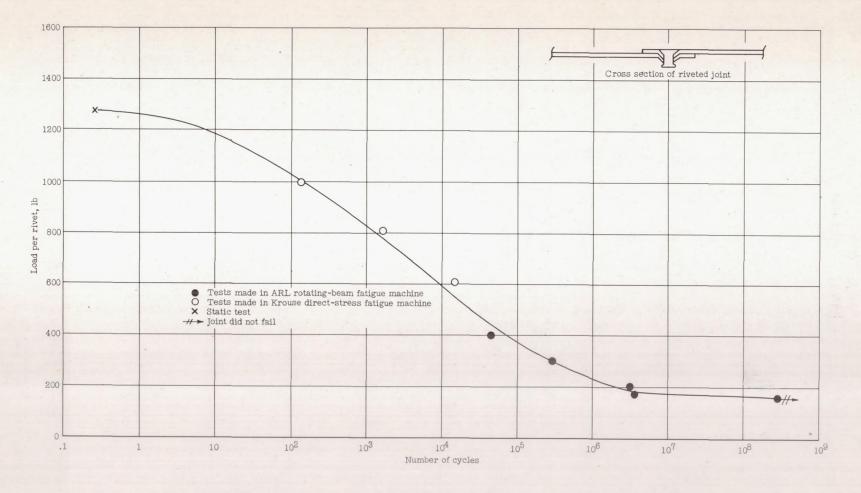


Figure 21.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk rivets driven in spin-dimpled holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 44, table II of present paper. All tests made with complete reversal of stress.

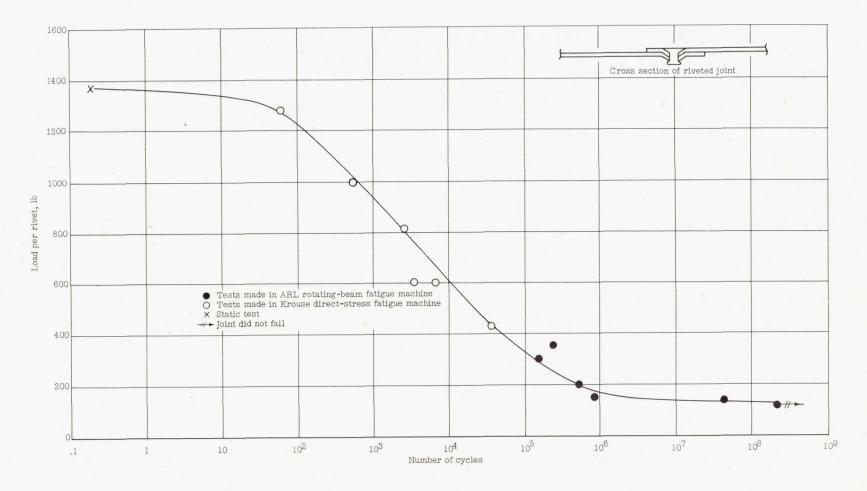


Figure 22.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 17S-T31 countersunk rivets driven in spin-dimpled holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 45, table II of present paper. All tests made with complete reversal of stress.

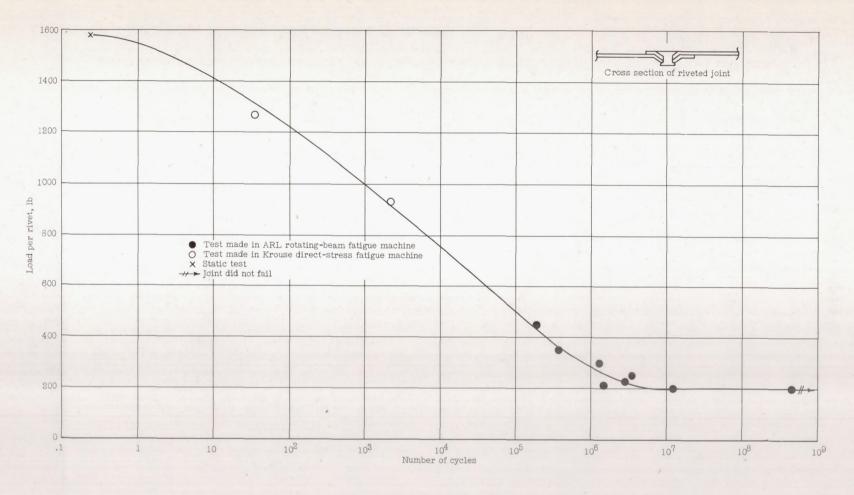


Figure 23.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk rivets driven in coin-dimpled holes (dimpled "cold" at room temperature). Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 52, table II of present paper. All tests made with complete reversal of stress.

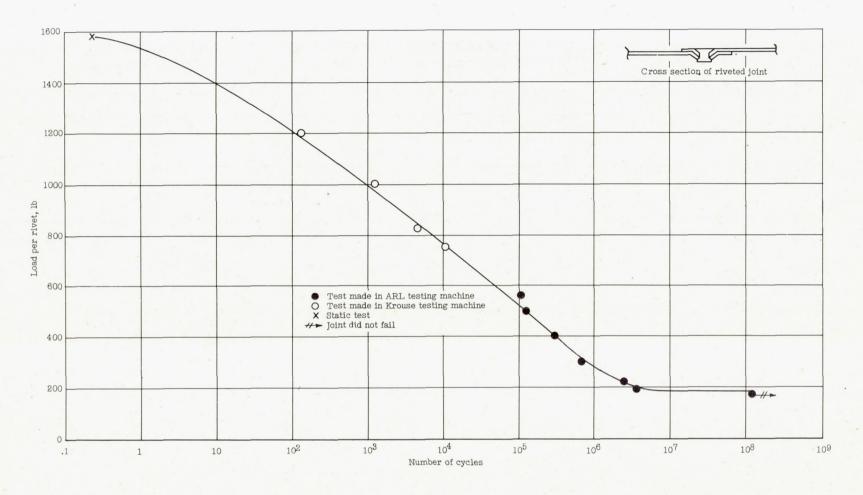


Figure 24.- Shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk rivets driven in coin-dimpled holes (dimpled "hot," with heated tools). Specimen, Alclad 75S-T sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 53, table II of present paper. All tests made with complete reversal of stress.

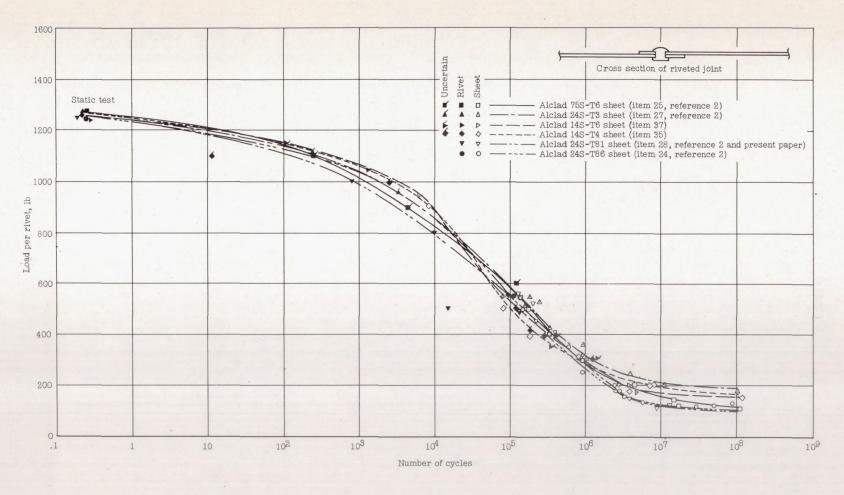


Figure 25.- Results of shear fatigue tests of joints with $\frac{3}{16}$ -inch-diameter 24S-T31 brazier-head rivets driven in drilled holes. Specimens, Alclad sheet 0.064 inch thick by 1 inch wide, various alloys and tempers. All tests made with complete reversal of stress.

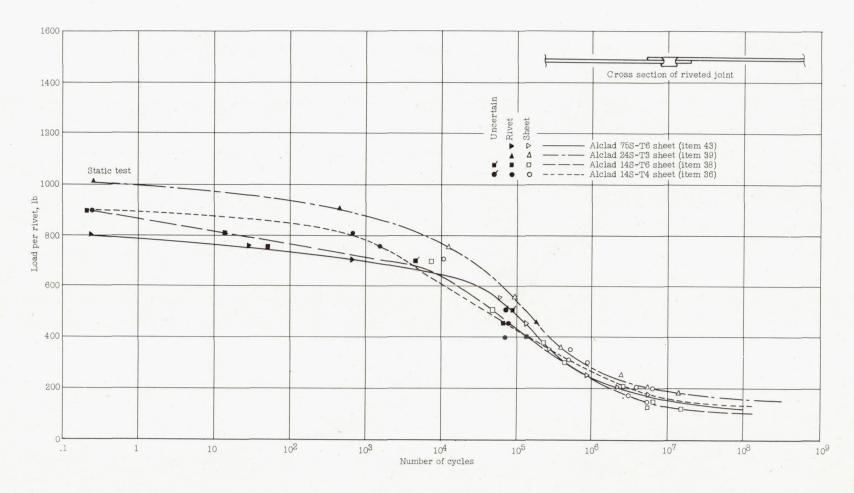


Figure 26.- Results of shear fatigue tests of $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk-head rivets driven in machine-countersunk holes. Specimens, Alclad sheet 0.064 inch thick by 1 inch wide, various alloys and tempers. All tests made with complete reversal of stress.

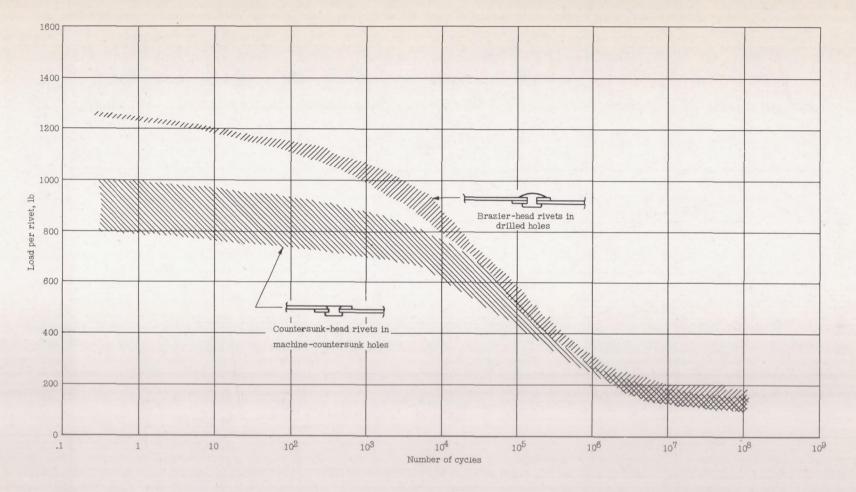


Figure 27.- Results of shear fatigue tests of riveted joints. Specimens, Alclad sheet, 0.064 inch thick by 1 inch wide, various alloys and tempers. Rivets, $\frac{3}{16}$ -inch-diameter 24S-T31, brazier-head in drilled holes and countersunk-head in machine-countersunk holes. Each scatter band includes Alclad 75S-T6, 24S-T3, 14S-T6, and 14S-T4. Band for brazier-head rivets also includes 24S-T81 and 24S-T86. All tests made with complete reversal of stress.

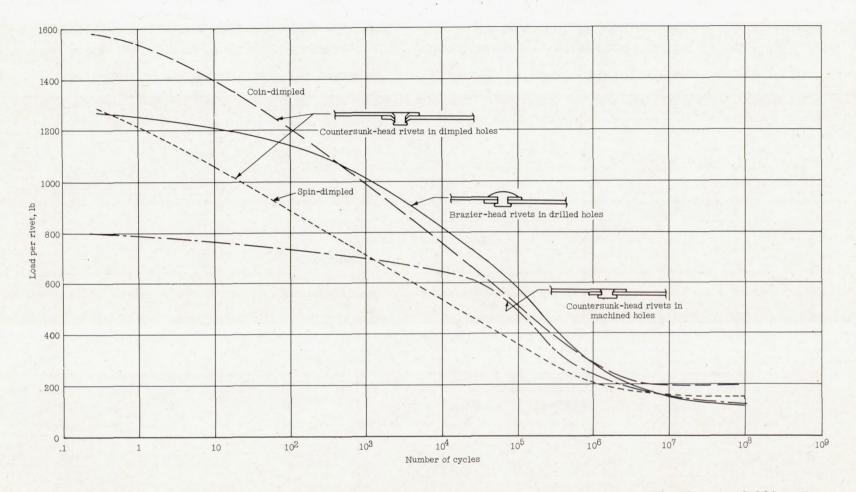


Figure 28.- Results of shear fatigue tests of riveted joints. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. Rivets, $\frac{3}{16}$ -inch-diameter 24S-T31, brazier-head and countersunk-head in different types of holes. All tests made with complete reversal of stress.

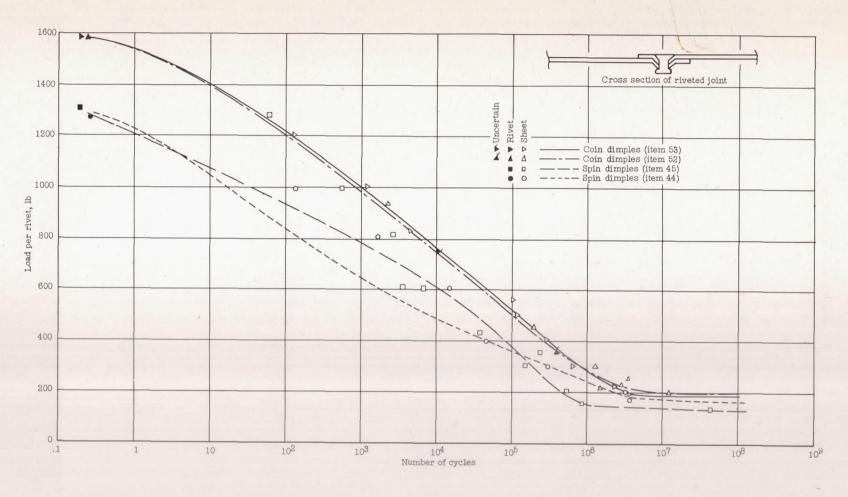


Figure 29.- Results of shear fatigue tests of riveted joints. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. Rivets, $\frac{3}{16}$ -inch-diameter 24S-T31 countersunk-head driven in holes coindimpled or spin-dimpled. All tests made with complete reversal of stress.